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COMPARATIVE STUDY OF PARTICULATE MATTER IN THE TRANSPORT MICROENVIRONMENT (BUSES) OF PAKISTAN AND UK

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ABSTRACT

Transport microenvironments can contain higher levels of particulate matter due to infiltration from the roads, vehicular exhaust and commuter's activities. The present study monitored PM, CO_2, CO, temperature and relative humidity levels in diesel-powered buses in Pakistan and United Kingdom. Two routes of almost the same travelling distance were selected in Pakistan and the UK. Indoor air quality of the buses was monitored to determine the exposure faced by the commuters on inter-city journeys. While the observed levels in both countries were not in compliance with the WHO guidelines, levels of particulate matter were much higher in Pakistan than the concentrations in UK.

Keywords: Transport microenvironment, Particulate matter, Pakistan, United Kingdom.

INTRODUCTION

According to World Health Organization, (2005) in Europe people spend 1-1.5 hours per day travelling. Among all daily activities, episodes of high exposure to air pollution are experienced via commuting, especially in those metropolitan areas where vehicle density is high (Duci *et al*., 2003). Concentrations of the air pollutants are higher around busy roads, and streets. It is more common in an urban commuting environment and mostly their levels peak during the morning rush hours (Morawska *et al*., 2008; Moreno *et al*., 2009). Individuals traveling for 6% to 8% time of their day in traffic are highly exposed to the elevated pollutants in transport microenvironments (Kaur *et al*., 2007). During the regular and daily journey, a commuter may be subjected to 12% of $PM_{2.5}$ exposure and 30 % of black carbon daily dose (Dons *et al*., 2011).

According to a number of studies, traffic related air pollution and short and long term exposure to particulate matter can trigger respiratory diseases and result in cardiovascular morbidity and mortality (Adar *et al*., 2007; Anderson *et al*., 2012).Various comparative studies have been conducted in order to determine the levels of air pollution in different modes of transport i.e. bicycle, car, buses and subways. Kaur *et al*. (2007) found that the particulate matter exposure encountered in busses and cars was comparatively higher than exposure during walking and cycling. In related studies by Adams *et al*. (2001) and McNabola*et al*. (2008), the exposures of $PM_{2.5}$ levels were found to be highest in busses, followed by cars and lowest during walking and bicycling.

The risks of particulate matter exposure to the bus users is dependent on many variables and differs from city to city, according to the traffic intensity and bus type (Karanasiou*et al*., 2014). A study by De Nazelle*et al*. (2012) conducted in Barcelona, showed that the exposure levels inside buses was lower than other transport modes, when the bus fleet was particularly modern in terms of choice of fuel i.e. 41% of the buses used natural gas as fuel, 8% were hybrid and 51% had installed selective catalytic reduction trap combined with continuously regenerating particulate trap. On the contrary, exposure of $PM_{2.5}$ to passengers in public buses of Dublin which were diesel fueled, were found to be highest as compared to other modes (McNabola *et al*., 2008).In diesel buses when compared with electric powered buses, exposure of particulate matter, black carbon and particle number counts was higher and the concentrations were lower in the driver's compartment as compared with the passenger cabins (Zuurbier *et al*., 2010).Personal exposure in transport microenvironments are also influenced by the factors other than the transport mode. These confounders include personal factors, transport conditions and routes, travel speed, between vehicle distances, ventilation, fuel type and meteorological conditions (Karanasiou *et al*., 2014).

These studies were carried out in metropolitan areas and data on exposure to particulate matter in inter-cities journey are rare. With an increasing concern towards traffic related air pollution in both the developed and developing countries, this study was conducted to investigate the present state of particulate air pollution inside bus microenvironments of Pakistan and UK during inter-city journeys. This study is intended to offer insights into levels of the PM and seeks to explore the potential factors influencing them.

MATERIALS AND METHODS

Study sites: Various particulate matter fractions were monitored in transport microenvironment (buses) of Pakistan and UK (Fig. 1). The in bus monitoring of particulate matter along with temperature, relative humidity, carbon dioxide and carbon monoxide in Pakistan was done on two routes i.e. Lahore to Islamabad and Islamabad to Lahore via Motorway (M-II). Likewise in UK the fractions were measured in the bus from London to Birmingham and the return journey i.e. Birmingham to London via M6. The study was carried out in the winter season. The buses were air conditioned and diesel fueled.

Fig.1. Map highlighting the routes covered by buses of UK and Pakistan

Data Collection: The mass concentrations of the various PM fractions were measured with a TSI DUSTTRAK DRX Aerosol Monitor (Model 8533). The levels of CO_2, CO, temperature and relative humidity were measured by BW Gas Probe IAQ.

Along with the in-bus monitoring on these routes, the experimental setup was also installed on the bus stations before departure and after the arrival of the bus at its particular destination. At the bus stations, the number of people and buses with running engines were noted. Inside the buses, number of passengers, activities and opening and closing of the doors was also taken in an account.

RESULTS AND DISCUSSION

In Pakistan, the levels of various PM fractions, temperature, relative humidity, carbon dioxide and carbon monoxide were monitored for a 6 hours journey from Lahore to Islamabad and Islamabad to Lahore. Likewise in UK the monitoring was carried out for 5 hours from London to Birmingham and Birmingham to London.

Figure 2 depicts the 15 minutes average concentration of PM along with various recorded activities. From Lahore to Islamabad, the departure time of the bus from Lahore bus station was 1:00 A.M. but monitoring was started at 12:30 A.M. at the bus station. It was observed that three buses were idling and number of people was approximately 50. Monitoring inside the bus started at 1:00 A.M. and was terminated at 5:10 A.M. The number of passengers was 47.

PM values fluctuated throughout the journey (Fig. 2). Figure 3 illustrates the average, hourly maximum and hourly minimum PM concentrations during the journey from Lahore to Islamabad. The concentration of carbon monoxide was observed to be below the detection limit. Carbon dioxide levels were found to be quite high with an average concentration of 2227ppm. The average concentrations of temperature and relative humidity after the 6 hours of sampling were found to be 24°C and 54%.

On the journey from Islamabad to Lahore, sampling started at 6:40 P.M. on Islamabad bus station. On the station, the number of running buses was 4 and 40 people were present. The bus departed at 7:00 P.M. and arrived in Lahore at 11:20 P.M. The number of passengers in the bus was 30. Average concentrations of PM fractions after every 15 minutes are given in Fig. 4. The 6 hours average PM concentration was 243µg/m³. Figure 5 illustrates the average, hourly maximum and hourly minimum PM concentrations during the journey from Islamabad to Lahore.

Unlike the journey from Lahore to Islamabad, CO was detected i.e. maximum concentration was found to be 4ppm (Table 1). This concentration was noted at the start of the journey when the bus was on the bus station and exhausts from running engines could be the source. The average carbon dioxide concentration was 1316 ppm with average relative humidity of 45% and temperature 25°C.

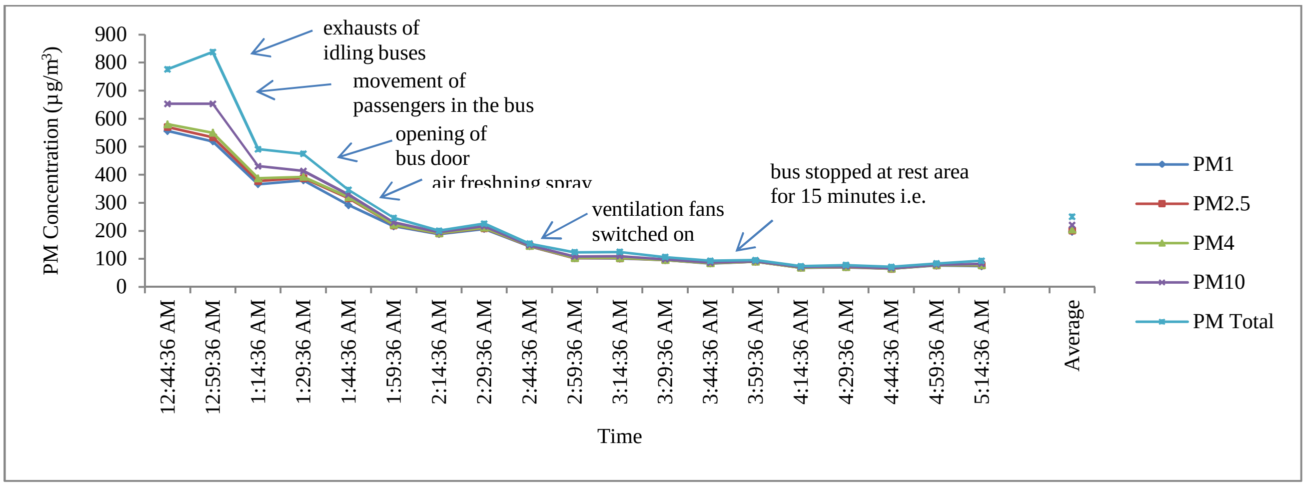

Fig.2.Average concentrations (at 15 minutes interval and total 6 hours) of PM fractions in journey from Lahore to Islamabad

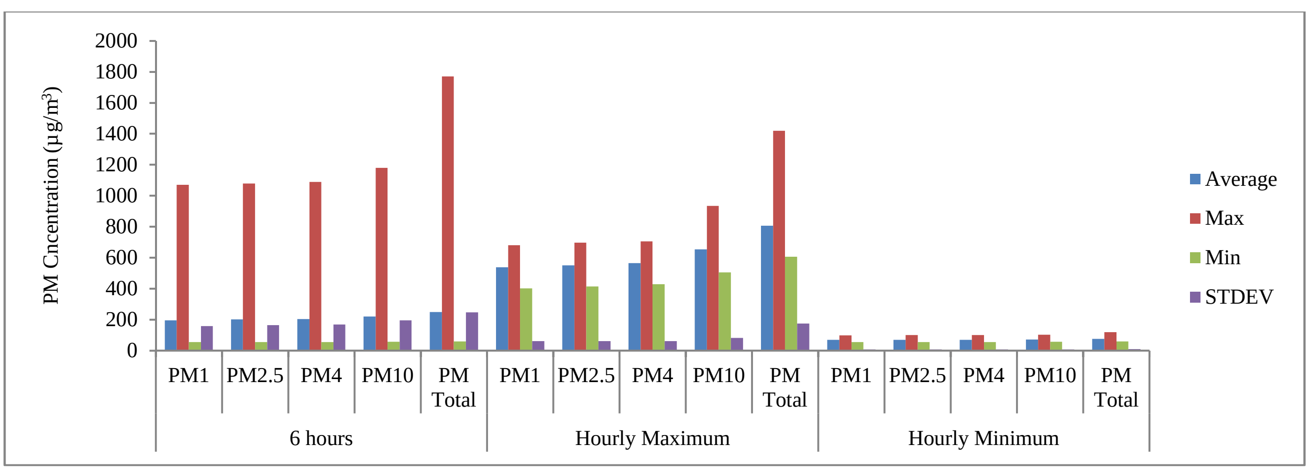

Fig.3. Average, hourly maximum and hourly minimum PM concentrations during the journey from Lahore to Islamabad

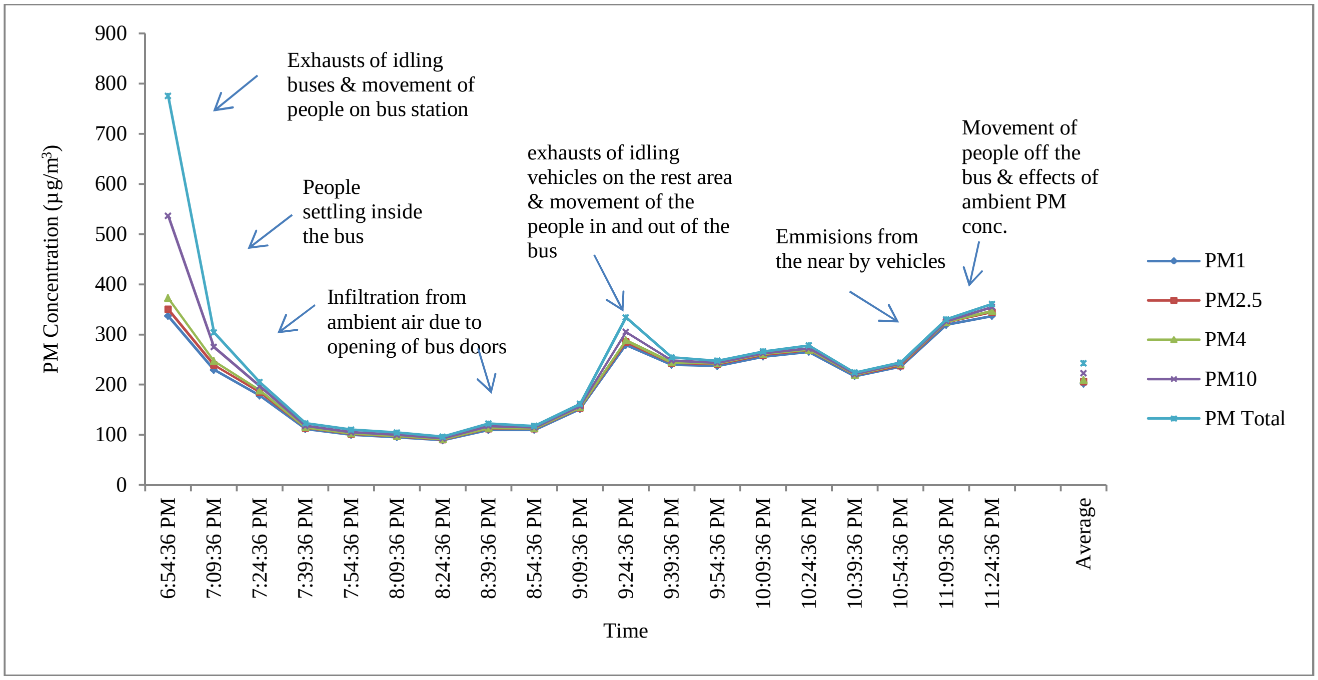

Fig.4. Average concentrations (at 15 minutes interval and total 6 hours) of PM fractions in journey from Islamabad to Lahore

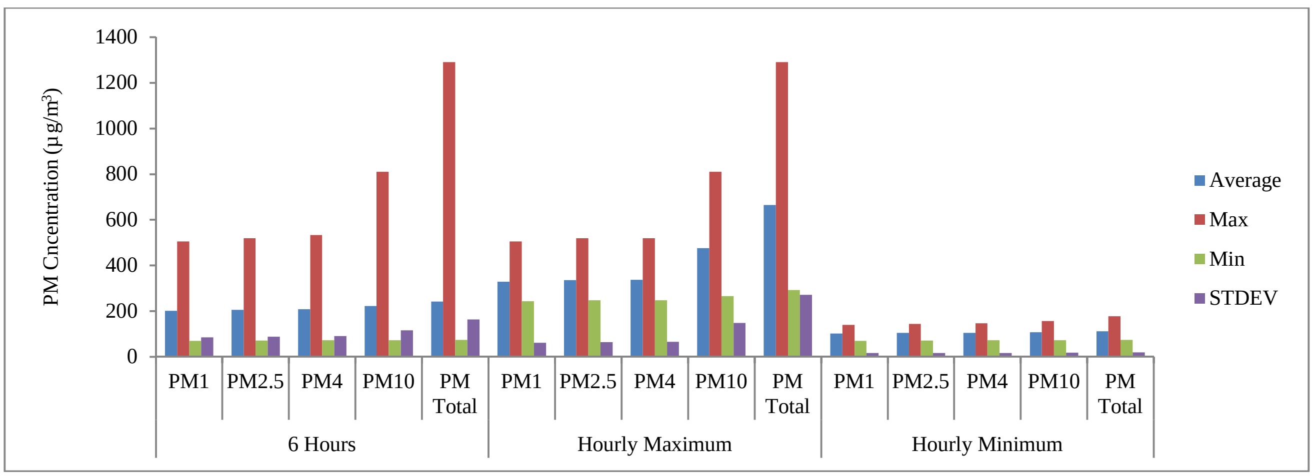

Fig.5. Average, hourly maximum and hourly minimum PM concentrations during the journey from Islamabad to Lahore

For London to Birmingham monitoring started at Victoria Station, London at 12:30 A.M. The number of people at the station was 76 and the number of idling buses was 6. In-bus monitoring was started at 12:55 A.M. The bus reached Birmingham at 3:50 A.M. and sampling continued until 4:45 A.M. The number of passengers in the bus was 17. The number of people at the bus stop in Birmingham was 19 and 4 buses were found to be idling around.

During the sampling from London to Birmingham, factors such as neighboring vehicular exhaust, emissions from running engines and movement of people served as potential causes of variations in PM levels (Fig. 6). The PM_{total} concentrations were found to be 57µg/m³. Figure 7 illustrates the average, hourly maximum and hourly minimum PM concentrations during the journey from London to Birmingham.

$CO_2$was varying throughout the monitoring hours and the average concentration was 671ppm. Average temperature and relative humidity levels during the journey from London to Birmingham were 18°C and 58%.

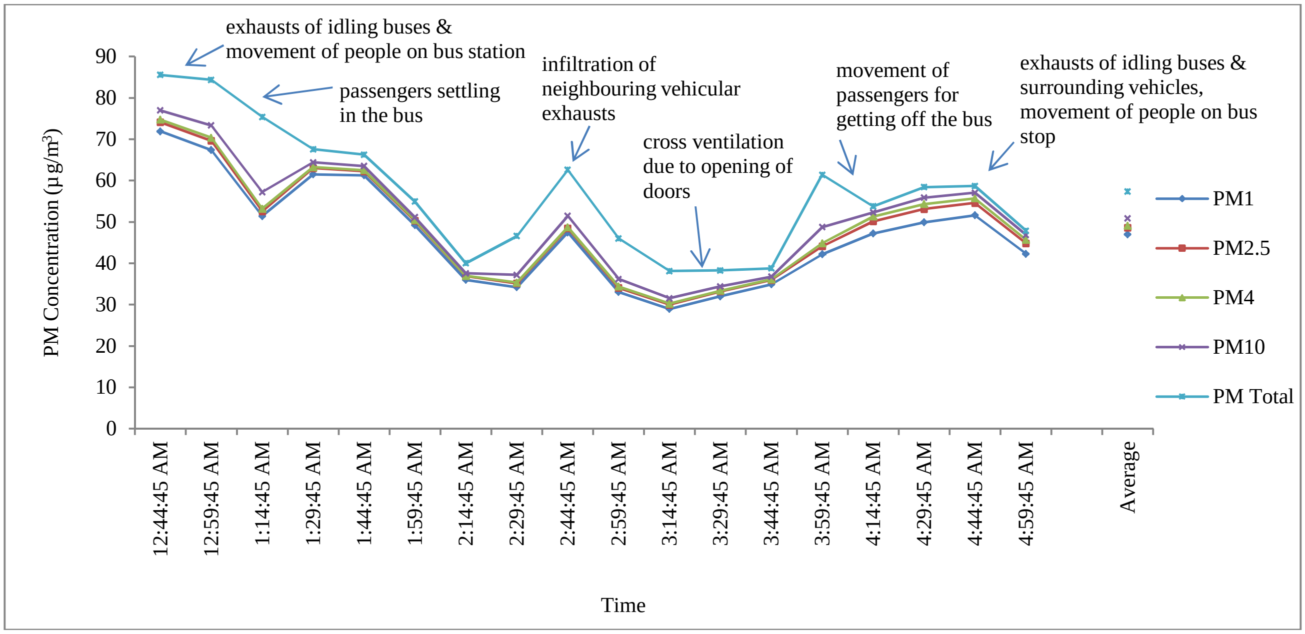

Fig.6. Average concentrations (at 15 minutes interval and total 6 hours) of PM fractions in journey from London to Birmingham

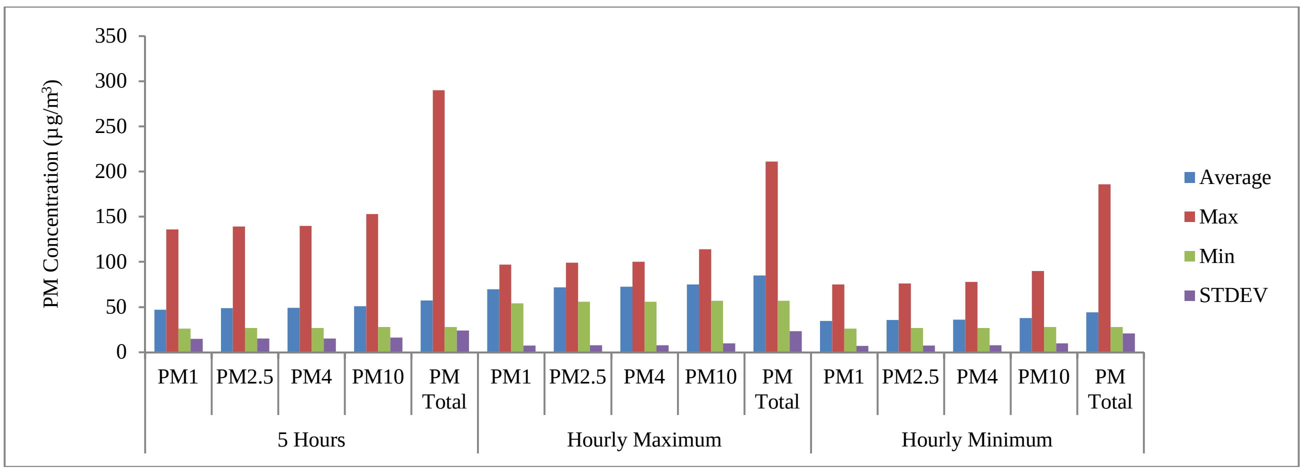

Fig.7. Average, hourly maximum and hourly minimum PM concentrations during the journey from London to Birmingham

From Birmingham to London, monitoring was started at the bus station at 6:40 P.M. The number of people at the station was counted to be 150 and number of running buses was 7. In bus monitoring started at 6:55 P.M. and ended at 9:50 P.M. The number of passengers was 37. The monitoring was carried on at the London bus station until 10:15 P.M. The number of idling buses was 4 and number of people passing by was 94.

Average concentrations of PM are shown in Figure 8. Figure 9 illustrates the average, maximum and minimum PM concentrations during the journey from Birmingham to London.Average carbon dioxide was 1424ppm with 55% relative humidity and 21°C temperature.

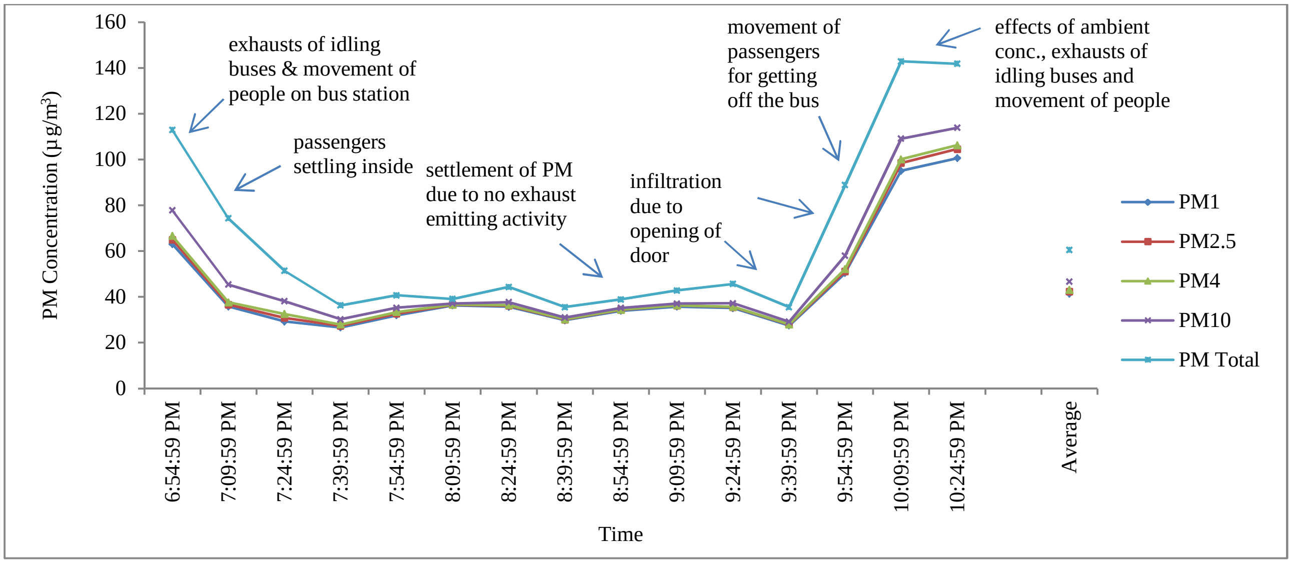

Fig.8. Average concentrations (at 15 minutes interval and total 6 hours) of PM fractions in journey from Birmingham to London

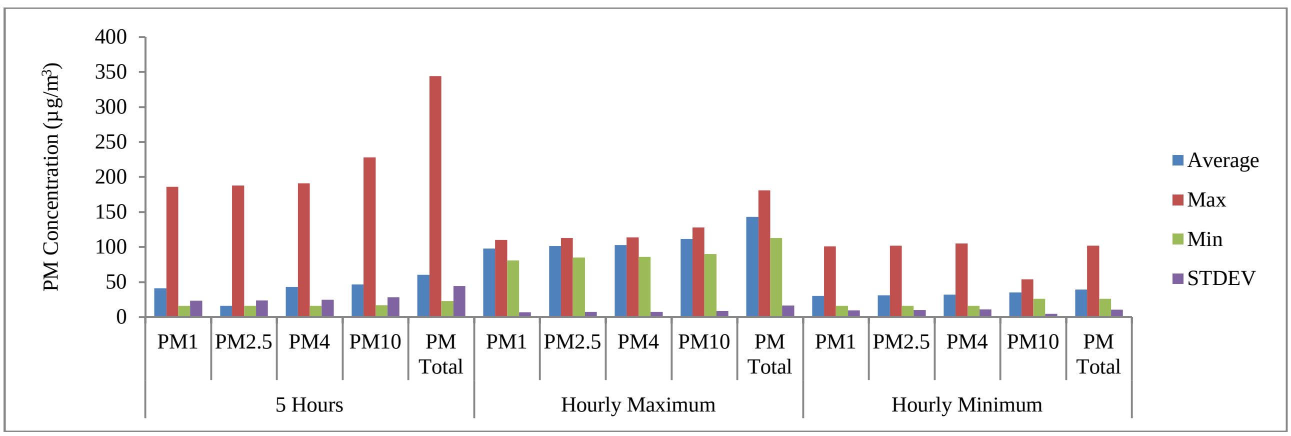

Fig.9. Average, hourly maximum and hourly minimum PM concentrations during the journey from Birmingham to London

As observed in the figures, factors such as exhausts from running engines, movement of people on the bus stations and movement of passengers in and out of the bus play a major role in the fluctuating PM levels. In areas with intense traffic densities and during the peak traffic hours, the exposure to particle number concentration was found to be higher (Diapouli*et al.*, 2008). Activities such as opening and closing of doors on the highways also resulted into varying trends of PM. Infiltration of the vehicular exhaust from the surroundings inside the bus resulted in peaks. Dor*et al.* (1995) showed that in a moving vehicle the pollutant levels considerably depend on the exhausts and emissions of the vehicles moving around it. As seen in the results ventilation is one of the most important determinants of exposure levels in buses and high ventilation rates either provided by fans, open windows or natural leakages resulted in rapid infiltration of the outdoor pollutants in passenger cabins (Zuurbier*et al.*, 2010; Knibbs*et al.*, 2011).

Carbon dioxide levels can be used to determine ventilation in an enclosed environment. According to a European Standard i.e. EN 13779: 2007 levels of CO_2 greater than 1000ppm above the outdoor air reflect poor indoor air quality. Table 1 shows that the average concentrations of CO_2 in buses all exceeded 1000pppm.In order to get an effective comparison between UK and Pakistan, sampling was done in the winter season to match the weather conditions of Pakistan with the cold climate of UK. Comparison of PM fractions and other parameters can be seen in Table 1, which demonstrates the average, maximum and minimum concentrations of the sampled parameters for each inter-city journey route.

It is evident that the levels of the PM in Pakistan are 3 to 4 times higher than those observed in the UK. Factors such as poorly maintained traffic conditions in

Pakistan along with the use of ill maintained vehicles for transport play a major role in the occurrence of such differences. These confounders not only include the transport conditions and routes but also factors such as personal activities, travel speed, between vehicle distances, ventilation, fuel types and the meteorological conditions.

During commuting, the exposure levels are influenced greatly by the route i.e. high or low traffic density and the emissions produced from the vehicles. Dons *et al*. (2012, 2013) detected that during the traffic rush hours, the black carbon concentrations in-cars were found to be 2µg/m^3 greater than the average concentrations. Travel speed is greatly related with pollutant exposures. Dons *et al*. (2013) observed that the concentration of black carbon in vehicles was found to be higher at lower speeds. Another influencing parameter for personal exposure is the fuel type. Zuurbier*et al*. (2010) found that the exposure levels in diesel fueled cars and buses were greater than in electric powered vehicles. Meteorological parameters especially wind speed and relative humidity affect personal exposures to $PM_{2.5}$ and CO, higher wind speed decreases the exposure and high humidity increases it (Alam*et al*., 1999).

Table 1.Comparison of average, maximum and minimum concentrations of all sampled parameters in buses during the inter-city journey routes.

Sampled Parameters		LHR - ISL	ISL – LHR	LDN - BHAM	BHAM – LDN
	Ave	197	202	47	41
PM_1 (µg/m^3)	Max	1070	506	136	186
	Min	55	71	26	16
	Ave	202	207	49	16
$PM_{2.5}$ (µg/m^3)	Max	1080	519	139	188
	Min	56	72	27	16
	Ave	204	209	49	43
PM_4 (µg/m^3)	Max	1090	534	140	191
	Min	56	73	27	16
	Ave	220	223	51	47
PM_{10} (µg/m^3)	Max	1180	811	153	228
	Min	57	73	28	17
	Ave	250	243	57	60
PM_{total} (µg/m^3)	Max	1770	1290	290	344
	Min	60	74	28	23
	Ave	2227	1316	671	1424
Carbon dioxide (ppm)	Max	3301	1814	1154	2062
	Min	687	618	458	682
	Ave	0	0	0	0
Carbon monoxide (ppm)	Max	0	4	0	0
	Min	0	0	0	0
	Ave	24	25	18	21
Temperature (°C)	Max	28	27	23	24
	Min	18	19	7.3	16
	Ave	54	45	58	55
Relative Humidity (%)	Max	84	50	95	65
	Min	43	38	40	39

*LHR=Lahore, ISL= Islamabad, LDN= London, BHAM= Birmingham, Ave= Average, Max= Maximum, Min=Minimum

Conclusion: Lying on different continents both Pakistan and UK exhibit a wide variation in the levels of particulate matter and the related parameters. Exposure to PM and other parameters in buses during the intercity journeys exceed limits of WHO. The risk of exposure to PM is higher indoors not only because of the passenger activities and inadequate ventilation inside the buses but PM levels in the ambient air and other outdoor sources such as exhaust of neighboring vehicles play a key role. Thus there is a need to understand that integration of transport policies involving actions such as the withdrawal of poor and aged private vehicles and renovation of the existing public vehicles can reduce traffic related air pollutant exposure to a commuter. Along with these, there is a need to promote the use of public transport more, rather than private automobiles.

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